sketch-book and drawing implements. The practical teaching of the "preliminary men" is, on the whole, guided by "Bower and Vines' Practical Botany." A sufficient supply of material for these men is always kept in spirit, but fresh specimens are examined whenever this is required and the season is favorable. A collection of microscopical preparations illustrating Bower and Vines' book is kept in order to be shown whenever a student, after several attempts, fails to get a sufficiently good preparation himself. The middle part of the room is occupied by two large tables, which serve for various purposes at different times and are very useful. Along the rear wall there is a bench with several sinks for washing plants, bottles, etc., several warm chambers, imbedding apparatus, Bunsen burners, etc. Above these are several shelves on which a great many things frequently used are placed, such as jugs, dishes, bottles, a rough balance, a distilling apparatus, large bottles containing spirit, solutions of chromic acid and picric acid, common salt, distilled water, smaller bottles filled with potash, soda, several acids, alcohol of different strengths, Schultze's macerating fluid, etc. Along the other walls there are cupboards, in which a pretty large collection of systematically arranged materials for investigation, chiefly preserved in spirit, is kept. The material for the "preliminary men" is kept separate or arranged according to Bower and Vines' book. There are also a number of smaller cupboards, each with a separate key, in which the students keep their private property. In describing our laboratory I have endeavored to enumerate at the same time most things necessary for a botanical laboratory. In conclusion I may mention that anybody interested in the construction of a new laboratory will find much useful information in a book by E. C. Robins, entitled, "Technical School and College-Building." (London, 1887. Whittaker & Co.)

Oxford, England.

Zygomorphy and its causes. III.

CHARLES ROBERTSON.

When shallow gamopetalous flowers become horizontal, they are subject to the same conditions as polypetalous flowers, and, like them, are apt to become sternotribe.

The flower of Campanula Americana[22] looks outward and a little downward, and would be regular but for the curvature of the style. The genus is actinomorphic, but this species is in the first stage of zygomorphy. Bees light upon the flower in such a way that the ventral surface of the abdomen strikes the pollen-bearing style in the male stage and the open stigma in the female stage. The style is bent down, so that the epigynous nectary is only accessible on the upper side. The uppermost flower of the spike commonly blooms before many of those below it. This flower often stands nearly erect and its style is nearly straight, so that it has much the same insect relations as in a terminal regular flower.

Deep gamopetalous flowers with exserted stamens and styles are also visited by insects lighting on these organs. They become sternotribe, access to the tube being on the upper side. In Lonicera one lobe forms the lower lip, while there are four in the upper, illustrating the tendency of sternotribe flowers to develop the attraction above the landing.

When a deep gamopetalous flower with included stamens and styles becomes horizontal, the convenient landing is on the lower side of the tube. The insect crawls back under the stamens and styles, so that these organs strike it on the back. The flower is, therefore, nototribe from the start, and it becomes advantageous for the organs to bend to the upper side of the flower and turn the anthers and stigmas so that they will strike the insect more effectually.

The lower nectary is most convenient, since it is in front of the landing. When the stamens and styles turn to the upper side of the flower, they make the lower nectary more convenient and the upper more inaccessible. A single nectary may be retained on the lower side, or an originally central nectary may become more strongly developed or only accessible on the lower side.

That these conditions in the insect relations have led to the production of nototribe flowers is supported by the fact that such flowers belong to gamopetalous orders, Scrophulariaceæ, Labiatæ, etc.

But some flowers belonging to these orders are sternotribe, such as Scrophularia.

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[22] For an account of the proterandry of this plant and figs. see Barnes, Bot. Gaz. X. 349, and pl. X, figs. 2 and 3. The flower is adapted to the larger bees, Apidæ. I have seen the following insects on the flowers: Hymenoptera—(a) *Apidæ:* (1) Bombus Virginicus Oliv. (mn); (2) B. separatus Cress. (m); (3) B. Pennsylvanicus De Geer (n); (4) Apathus elatus Fabr. (m); (5) Melissodes bimaculata St. Farg. (mn); (6) Megachile brevis Say (f); all sucking as described above; (b) *Andrenidæ:* (7) Halictus sp. (f); (8) Augochlora pura Say (f); both collecting pollen; (9) Prosopis affinis Sm. (f); eating pollen. The Andrenidæ behaved dysteleologically, only visiting flowers in the male stage. (c) *Sphecidæ:* (10) Ammophila sp., trying to find nectar. Lepidoptera—(a) *Nymphalidæ:* Pyrameis cardui L., trying to find nectar.

Under S. nodosa H. Müller[23] says: "In most Lamiales and Personales the anthers lie in two pairs, one behind the other, and touch an insect visitor on the dorsal surface; the stigma then, to insure cross-fertilization, must also touch the insect on the back, and the style can scarcely lie elsewhere than between the two pairs of stamens, along the upper part of the corolla. The superior stamen comes in the way, and accordingly disappears; it has no chance of reappearing permanently, for it is directly injurious, and is weeded out by natural selection." * * "In Scrophularia, on the other hand, the anthers come in contact with the ventral surface of the insect. The fifth stamen is thus useless but not injurious; whether it be present or absent is of no importance, and it is therefore beyond the influence of natural selection. Accordingly, the small black scale-like appendage on the upper wall of the corolla in Scrophularia, which represents the fifth stamen, shows not unfrequently more or less complete reversion to its primitive form." It seems to me to be more consistent with the affinities of Scrophularia to suppose that the fifth stamen was aborted under the same conditions as in other didynamous flowers, and that the organs formerly occupied the upper side of the corolla. This will relieve us of the embarrassment of explaining the abortion of the fifth stamen under the influence of natural selection in most Scrophulariaceæ and "beyond the influence of natural selection" in Scrophularia. The antheriferous condition of the filament need not give us any trouble, but may rather confirm the supposition, since it is a plain indication that the conditions which led to the abortion of this stamen no longer exist to keep it reduced. I believe that the flower was originally adapted to bees, which squeezed into the tube, and that it has become shallow in adaptation to wasps. Increase of shallowness has had the effect of exposing the stamens, so that insects could light upon them, and they have therefore turned to the lower side. If the flower was originally shallow, and was visited by insects lighting on the stamens, I see no reason why the upper stamen should have been left behind.

There are other examples of sternotribe flowers belonging to nototribe types, but the reduction of the upper stamen in all, or most of them, is an indication that the organs were once crowded in the upper part of a narrow tube. There is generally no tendency to abortion of the stamens in sterno-

[23] Fertilization of Flowers, 434.

tribe flowers, since, the flower being shallow, there is room for many stamens without crowding.

We have observed that sternotribe flowers may become nototribe by inverting, and now it appears that nototribe flowers may become sternotribe by becoming shallow, or by having their stamens and styles exserted. An observation of H. Müller on the flower of Odontites serotina shows how it might be advantageous for the stamens to turn to the lower side of the flower, and may help us to understand the case of Scrophularia. He says:[24] "The upper lip, as the figure shows, projects so slightly that the anthers in great part protrude beyond it and are unprotected. This is sometimes the case to such a degree that bees thrust their tongues into the flower above the stamens and thus suck honey and shake out the pollen without leading to fertilization."

By reduction in size and close crowding, associated with an exsertion of the stamens and styles, some labiate flowers have lost the insect relations which I think have modified them. Like Amorpha, they are fertilized by insects crawling over the inflorescence. In this way Lophanthus[25] seems to have lost much of its labiate character.

In the foregoing it is claimed that the original visitors must have lighted on some part of the flower, and that the character of the irregularity depended on whether the place of lighting was below or upon the sexual organs. But some irregular flowers are specially adapted to humming-birds and hawk-moths, which suck without lighting.

The fact that most zygomorphous flowers are bee-flowers indicates the importance of bees as the principal visitors. The importance of bees in producing the modifications is even greater than is at present indicated by the flowers; for I think there is reason to believe that most, if not all, of these flowers which are not adapted to bees were originally modified by them and have been usurped by other visitors.

Humming-birds and hawk-moths fly so rapidly and suck so easily that it is not hard to understand how they might take possession of bee-flowers which suit their fancy. Flowers adapted to them vary in position from erect to pendulous, and they can suck all of these with equal convenience and without lighting. If they visit regular horizontal flowers, they are not influenced by any place of landing and can suck one nectary as conveniently as another, so that there is no

[24] Fertilization of Flowers, 446.

[25] See Foerste on L. nepetoides, Am. Nat. XVIII, 928.

advantage in the organs turning to any particular side. But zygomorphous flowers adapted to these kinds of visitors follow the same rule as those adapted to bees, *i. e.*, those of shallow origin are sternotribe and those of deep origin are nototribe. Therefore, I believe that they were originally adapted to bees which lighted on some part of the flower.

Many flowers adapted to humming-birds and Sphingidæ have a well developed landing which they could have had no influence in producing. This is shown by the fact that this part is sometimes much reduced in flowers adapted to them, as in Salvia splendens,[26] a bird-flower which belongs to a melittophilous genus. That birds have no influence in producing zygomorphous flowers is indicated by Lonicera sempervirens, which is more regular than the species visited by bees. Flowers originally modified by Sphingidæ are regular, like Datura, Convolvulus, etc.

Many flowers adapted to bees show butterflies, Sphingidæ and humming-birds as intruders, and this is important, since it enables us to understand how bee-flowers might become modified to suit them.

Linaria is a good example of a melittophilous genus. The broad tube is suited to bees, and the palate, which seems to be intended to exclude butterflies and flies, is easily opened by bees. H. Müller found L. vulgaris[27] visited exclusively by bees (8 species). In Illinois I found it visited by 5 species of bees and 4 species of butterflies. L. alpina, according to Müller,[28] is adapted to humble-bees, but is visited by Lepidoptera also. In Florida I found L. Canadensis visited by bees, but much more frequently by butterflies. The spur is very slender, and the tube has become so contracted that bees can only insert their tongues, and butterflies can not suck without touching the anthers and stigma. The palate seems to have lost its function, for it is so weak that it entirely fails to exclude butterflies or even flies. I have seen three flies sucking and eating pollen—*Toxophora amphitea*[29] Walk., *Mesograpta marginata* Say and *Baccha Babista* Walk. The color and other characters of this flower are melittophilous, yet it is modified to suit butterflies, which have become the predominant visitors.

Delphinium is adapted to bees, as far as observed. But Müller saw D. Consolida visited by butterflies, Hesperia and

[26] See Trelease Am. Nat. XV, 265.
[27] Fertilization of Flowers, 432.
[28] Alpenblumen, 275.
[29] The flies mentioned in this paper were named by Dr. S. W. Williston.

Satyrus. I have seen D. tricorne visited by 6 species of bees and 7 species of butterflies. Here is a bee-flower in which the number of species of butterflies exceeds the number of bees. The spurs point upward more or less directly, so that, while bees have no difficulty in clinging to the flowers, butterflies, which prefer erect flowers, are put to considerable inconvenience, especially the Papilios, which generally suck with their wings in motion.

One cause of a change of visitors in flowers of shallow origin is probably the inversion of the flower. If the flower of Delphinium tricorne should become inverted, the bees, being thus deprived of their accustomed landing, could not suck the flowers so easily, while the butterflies could suck with more ease.

The views expressed above may be summed up in the following propositions:

1. When shallow flowers become horizontal, insects light on the stamens and styles and prefer the upper nectary.

2. The stamens and styles bend to the lower side, and the lower nectaries abort.

3. Zygomorphous flowers of shallow origin are sternotribe, and have a single nectary present, or a central nectary more strongly developed or more accessible, on the upper side.

4. Nototribe flowers of shallow origin are inverted.

5. When regular tubular flowers with included stamens and styles become horizontal, insects land on the lower border and prefer the lower nectary.

6. The stamens and styles bend to the upper side, and the upper nectaries abort.

7. Zygomorphous flowers of deep gamopetalous origin are nototribe and have a single nectary present, or a central nectary more strongly developed or only accessible, on the lower side.

8. Sternotribe flowers of deep gamopetalous origin have originally exserted stamens and styles (Lonicera), or have become shallow (Scrophularia).

9. Irregular flowers were modified with reference to a landing place,[30] and were modified through the influence of insects lighting upon them.

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[30] (2) Die Honigbehälter sind auf derfenigen Seite der Blume entweder nur vorhanden oder doch stärker entwickelt, auf welcher sich die Aufliegestelle (!) für die Insekten befindet.

(3) Die Staubgefässe wenden ihre Beutel mit den Oeffnungseiten der Aufliegestelle (!) der Insekten zu; daher im ganzen auch den Honigbehältern. Jordan, Stellung der Honigbehälter und der Befruchtungswerkzeuge in den Blumen, 54.

10. Irregular flowers adapted to insects which do not light have changed visitors.

11. Small, closely-crowded flowers do not tend to become zygomorphous.

12. Small, closely-crowded, irregular flowers are liable to lose their zygomorphous characters, unless the stamens and styles are protected by galeæ, carinæ, etc.

Carlinville, Ill.

Proceedings of the Botanical Club.

WEDNESDAY, AUGUST 15, 1888.—The Botanical Club of the A. A. A. S. was called to order by the President, David F. Day, who spoke a few words of welcome and good cheer. Considering the time, the attendance was excellent. In the absence of the Secretary, Prof. V. M. Spalding, Rev. William M. Beauchamp was elected Secretary *pro tem.*

Mr. Thomas Meehan read a paper on the elasticity of the filaments in Compositæ. Mr. Meehan pointed out the elasticity of the filaments of a few Compositæ in 1883, and brought the matter before the Association in 1884, when some questions were raised whether it was not irritability rather than elasticity that caused the behavior.[1] He now adds that the filaments of a large number of Compositæ are elastic (Heliopsis exhibits it most clearly), and describes an observation upon Helianthus doronicoides which shows that it is not irritability.

Mr. W. H. Seaman followed with some remarks upon the variation of Azalea nudiflora in respect to odor and viscidity. This species, when growing in high latitudes and on mountains, is quite viscid and odorous, while in lower ground and more southerly stations it is smoother and nearly odorless.

Mrs. H. L. T. Walcott corroborated the observation in regard to the species about Medford, Mass.

Mr. Meehan read a second paper upon gyno-diœcious Labiatæ. He added to the already-known species Nepeta grandiflora, a native of the Caucasus, and pointed out the differences between the hermaphrodite and pistillate plants. In the former the heads of flowers are more numerous, but less fertile, the flowers are much larger and more loosely spicate and the internodes longer. Mr. Meehan thought the

[1] See this journal, vol. IX, p. 158.